addition, extensive onsite pre-operational testing should be performed on all instruments and control systems associated with nuclear air cleaning systems prior to placing them in service to confirm correct installation and design and ensure operability.

The instrumentation and control systems associated with ESF air cleaning systems are intended to control the environment of the space served within the limits of the controlled variables and to monitor the performance of the system and its components to ensure safe, efficient, reliable operation. The design of instrumentation and control systems should consider the consequences of a single failure,2 [8] as well as prevalent environmental conditions.

The primary variables by which nuclear air-cleaning systems are controlled are airflow rate and pressure. Temperatures and radioactivity levels are also monitored to indicate system performance variables and to activate an alarm when abnormal conditions occur. Effluent air cleaning systems typically maintain minimum negative pressures, whereas habitability systems usually maintain a positive pressure in the space served.

Instrumentation should be provided to monitor the activity levels of all effluent discharges to the atmosphere, including airflow rate and concentrations of radioiodine, aerosols, and noble gases. Values in excess of established limits should trigger a local alarm and send an alarm signal to the main Control Room. Airflow rates and radioactivity levels for habitability systems should also be monitored and alarmed.

The best indicators of system performance for continually operating systems are radioactivity levels. Monitoring levels before and after air cleaning units indicates trends in filter degradation. In addition, controls should be provided to assist operators in monitoring system performance. Fire protection instrumentation should be based on the requirements of ASME N509[23] and the recommendations contained in Chapter 10.

2.7 SPECIAL CONSIDERATIONS

The special considerations discussed in this section are derived from experience gained in the design, construction, modification, and operation of nuclear facilities.

2.7.1 SEALING OF SPACES TO BE MAINTAINED AT A POSITIVE OR NEGATIVE PRESSURE DURING NORMAL/ACCIDENT MODES OF OPERATION

Many spaces of a commercial nuclear power plant require either a positive or negative pressure to be maintained between the space, the environment, and the adjacent spaces of the plant. Some examples are:

- Control Room
- Spent Fuel Pool
- Auxiliary Building/ECCS Pump Rooms
- Shield Building
- Technical Support Facility

Achieving this pressure differential requires special consideration of how well the spaces are sealed. Early in the design and construction of these areas, the need to properly seal them was not well understood by either the engineers or architects. As a result, when these areas/systems were placed in operation, the required pressure differential could not be achieved. Consequently, a great deal of backfit work had to be done to properly locate leak paths and develop and apply seals that would produce the required results. The following examples describe some of this backfit work.

Control Rooms. Control Rooms must be maintained at a positive pressure to ensure radiation is kept out of the Control Room during and after design basis events. Leaks were found around personnel entry doors, instrument and cable penetrations in walls and floors, cable penetrations under Safeguards Control cabinets, and ductwork penetrations. Remedies to these problems included replacement of some of the personnel doors with marine bulkhead-type doors and foaming large portions of walls and floors to seal around cable, instrument lines, and ductwork. Other personnel doors had to be fitted with leaktight seals to achieve the required pressurization. Rework, particularly foaming of penetrations, required several iterations to solve the leakage problems. In addition, many plants have experienced leaking ductwork that had to be sealed to meet the pressurization requirements.

Spent Fuel Pool. The Spent Fuel Pool must be maintained at a negative pressure during and following a fuel-handling accident to ensure that any release of radioactivity is filtered before release to the atmosphere. Leaks were found around cable, pipe, and ductwork penetrations and personnel doors. The leakage problems with the doors were solved by fitting the doors with seals. The penetrations were sealed with foam that also was required to meet the fire barrier rating of the walls.

Auxiliary Building/ECCS Pump Rooms. The ECCS Pump Rooms must be maintained at a negative pressure during and following design basis events to ensure that any leakage from the pump seals is filtered before release to the atmosphere. Leakage was found around personnel doors because the doors were not being closed as they should have been, and some were being propped open for the workers' convenience. In addition, the air balance in the building was incorrect, and the differential between the air supply and exhaust was insufficient to maintain the required negative pressure. Personnel doors were "controlled" by procedure to ensure their closure and remedy this problem. The air supply and exhaust systems for the Auxiliary Building were rebalanced and adjusted to ensure the proper differential was maintained to achieve the required negative pressure.

Shield Building. The Shield Building requires that a negative pressure be maintained during and after design basis events to ensure that any leakage from the primary containment is filtered before release to the atmosphere. There were no leakage problems associated with the pipe, cable, instrument, entry, and ductwork penetrations of the primary steel containment. This is because the primary containment has to be leaktight. Therefore, the initial designs for these penetrations ensured they were covered by the other requirements for building leakage. The primary problem occurred in the pipe, cable, instrument, entry, and ductwork penetrations of the concrete secondary containment. A great deal of rework had to be performed on these penetrations. The ductwork and piping required design of special seals; the cable and instrument penetrations required major adjustments to stop leakage; and the doors had to be fitted with seals and procedures had to be established to ensure their closure.

Technical Support Facility. The Technical Support Facility must be maintained at a positive pressure to ensure that any radiation is kept out of the area during and after design basis events and when the facility is manned. The leakage problems associated with the Technical Support Facility were associated with the same area penetrations as those in the Control Room. The problems were resolved in much the same way as those for the Control Room.

Although the examples cited above pertain to commercial nuclear power plants, the lessons learned and the problem solutions developed are applicable to any facility that requires maintenance of a differential pressure between it and surrounding areas.

2.7.2 MEASURING DIFFERENTIAL PRESSURE WITH RESPECT TO AMBIENT AND ADJACENT AREAS

In commercial nuclear power plants, periodic testing is required to demonstrate that the safety-related areas of the plant can be maintained at the required positive or negative pressures. Early testing protocol dictated that systems serving these areas be tested individually and at different intervals. Questions were raised about the effect that one HVAC system had on another (i.e., HVAC system interactions). For example, if the Control Room is required to be maintained at a positive pressure, what effect do the HVAC systems located adjacent to the Control Room (Turbine/Generator Building, Shield Building, and the Auxiliary Building) have on the Control Room pressure requirement? When these systems were tested in an accident line-up, the result was a negative effect on the Control Room. Consequently, additional sealing of the Control Room had to be performed so that the required positive pressure could be maintained. Most of these problems also resulted in Licensee Event Report (LERs) and were investigated by the USNRC.

Therefore, it is strongly recommended that all safety-related air handling and cleaning systems that have either a positive or negative pressure requirement be tested simultaneously because of these system interactions that can influence the pressure requirement in another area of the plant. In addition, some cases have been found where the worst scenario is not a loss of power where all of the safety-related systems are in operation, but rather normal system power availability. Therefore, some experimentation with various combinations of system operation is required to identify the worst-case testing condition.

2.7.3 System Operability during Maintenance, Repair, Testing, and Modification Activities

Commercial nuclear power plant technical specifications contain all of the requirements for the plant systems to be considered operable for power production. If a system must be shut down for maintenance, repair, testing, or modification, then the technical specifications dictate which resulting actions must be taken to allow the plant to continue operating. If these actions cannot be accomplished within the constraints of the technical specifications, then the plant must be shut down, with a resulting major loss of power and revenue to the owner. When power supplies are tight, this may also require the utility to purchase replacement power to maintain its level of service to its customers—an additional loss of revenue. Technical specifications have a time limit associated with these actions, and these time limits are strictly enforced.

Therefore, when performing repair, maintenance, testing, or modification activities, it is imperative that a detailed plan and schedule be in place prior to commencement of the activity. The plan must specify the time that is allowable to accomplish the work to be performed. As a general rule, for any work that involves a breach of the pressure boundary of the system (including the system ductwork, housings, walls, floors, or roofs of those areas that have a pressure requirement), compensatory actions must be taken to maintain the system's operability and to avoid an unnecessary plant shutdown or a violation of the plant's technical specifications. To accomplish this requires a detailed review and planning session prior to doing the work. It may also be necessary to practice the work on mock-ups before it is performed on the actual system. An example of a compensatory action that may be required is establishment of temporary administrative controls over doors or other openings to ensure these openings can be secured within a certain time frame if a design basis event occurs.

2.8 Emergency Considerations

The ventilation and air cleaning systems of a building in which radioactive materials are handled or processed are integral parts of the building's containment. In some cases, these systems may be shut down in the event of an operational upset, power outage, accident, fire, or other emergency. In other cases, they must remain operational to maintain the airflows and pressure differentials between building spaces and between the building and the atmosphere as required to maintain containment. In some of these cases, airborne radioactive material may not be a problem until an emergency occurs. In all cases, however, a particular danger is damage to or failure of the final HEPA filters (and adsorbers in those facilities where radiolytic gases could be released) that constitute the final barrier between the contained space (hot cell, glovebox, room, or building) and the atmosphere or adjacent building spaces. Even if the system can be shut down in the event of an emergency, protection of the final filters is essential to prevent the escape of contaminated air to the atmosphere or to allow personnel to occupy spaces of the building.

Consideration must be given to (1) the possible effects of operational upsets, power outages, accidents, fires, and other emergencies on the ventilation and air cleaning systems, including damage to the filters and adsorbers from shock, overpressure, heat, fire, and high sensible-moisture loading; (2) the design and arrangement of ducts and air cleaning components to alleviate these conditions; (3) the means of switching to a redundant air cleaning unit, fan, or alternate power supply; and (4) the methods of controlling or isolating the exhaust system during failure conditions. To provide the necessary protection to the public and plant personnel, the air cleaning and ventilation system components on which containment leakage control depends must remain essentially intact and serviceable under these upset conditions. These components must be capable of withstanding the differential pressures, heat,